Gamma Irradiation Effect on Quartz. (I)

A Mineralogical and Geological Application*

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Gamma irradiation was applied to the quartz of various rocks and synthetic one. And the different geological occurrences were clearly detectable by the wide range of the quartz smokiness grades. When irradiated by gamma-rays, the smokiness grade (*i. e.* quartz susceptibility to cobalt 60 gamma-ray irradiation) was the highest in volcanic rock quartz, intermediate in granite, and the lowest either in schist quartz or in low temperature quartz of hydrothermal origin. After the heating test of quartz at about 1000°C for 30 minutes, a marked increase of its smokiness grade was seen. Thus smokiness grade seems to indicate the crystallization temperature of that quartz. And the deep significance observed in this relation between the quartz smokiness and its crystallization temperature, appears to have been escaping the elaborate cosiderations of geologists and mineralogists. The gamma irradiation method must be applied to the study of granite petrogenesis and ore deposit, and also to be able to tell what the original rock of a quartz grain contained in a sedimentary one was.

INTRODUCTION

It has been well known that X-ray[1~7] and gamma-ray irradiation account for smoky quartz. While pleochroic halo, a phenomenon brought about by alpha particle radiation inside biotite flake, is of microscopic size, in case of smoky quartz the homogeneous coloration is as large as that quartz crystal, since gamma-ray can more easily permeate through rock minerals.

Fine crystals of smoky quartz, which are very common in pegmatite druse, have been fully studied physically, but the studies of rock quartz in the form of grains have always been neglected.

Quartz being distinctly sensitive to gamma-ray irradiation, its artificial smokiness grade seems to stand in an exact relation to its imperfect crystal structure.

In this paper, however, smoky quartz of rock was treated from geological point of view, and decolored quartz was exposed to gamma-rays, to compare it with naturally smoky one.

The gamma-rays used are of 2000 Curie cobalt-60 gamma-ray source[8], and for

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ROCK QUARTZ SAMPLES

From granite, quartz porphyry, liparite, quartz vein, quartz schist, etc. of different localities, quartz grains were selected by hand-picking to be crushed into the size of between 16 and 32 mesh. Their stains colored either by ferric of by manganic oxide were leached by immersing them in concentric HCl for 24 hours. These quartz grains thus leached mostly remain feebly smoky, on the one hand, as the result of the natural radioactivity, but on the other, as to how imperfect they are in their crystal structure[5].

Naturally smoky quartz can be decolored by heating it some 600°C for 5 minutes. The thus decolored samples were irradiated by cobalt gamma-rays (as a rule 10^7 roentgen). By the way, the repetition of such decoloring and coloring can not change the degree of quartz smokiness, so long as the conditions of these treatments remain the same. But before the susceptibility to gamma irradiation, *i. e.* the smokiness grade, of our quartz sample is tested, it must be as much decolored as possible by means of heating it for the sake of color comparison.

GAMMA IRRADIATION ON QUARTZ SAMPLES OF VARIOUS GEOLOGIC ORIGIN

Remarkable and geologically interesting is the difference of the smokiness grades exerted on quartz grains of divergent origins by the same dosage of gamma irradiation. The study of smokiness grades of rock quartz seems to inform us the conditions under which it crystallized in a wide variety of geologic occurrences.

Quartz samples were selected from granite (batholith type Ryoke granites, stock type — Tanakamiyama, Naegi and Kitashirakawa granites, Misasa granite, Hida granite gneiss and Korean precambrian granite) quartz porphyry, liparite, pegmatite, quartz vein and quartz of schistosed rock. Detailed petrological studies will soon be reported.

Quartz grains were irradiated by gamma-rays of the dosages of 10^5, 10^6, 10^7 and 10^8 roentgen, but 10^7 roentgen was nearly the dosage of saturation in case of cobalt-60 gamma-rays. According to Cohen[4], it was observed that the 950 mμ absorption band was saturated at 1.5×10^6 r, the 540 mμ at approximately 7.5×10^6 r, and the 340 mμ band intermediate between 0.75—2.1×10^7 r at the dosage of X-rays under the condition of approximately 2.5×10^4 r per minute. The two data—of the author's cobalt-60 gamma irradiation and of Cohen's X ray radiation—qualitatively agree with each other.

Only 0.2 to 0.5 gram of quartz samples is sufficient for naked eye comparison of their smokiness grades, but for the exact quantitative measurement of their reflection much more amount of quartz is needed.

GRANITIC QUARTZ

A large crystal of pegmatitic quartz very often shows a zonal structure of various smokiness grades, but the granitic samples are never heterogeneous in smokiness. In treating granitic quartz next two points will be discussed.

A. The contents of radioactive materials in the rocks and

B. Various genesis of rock quartz must always be taken into consideration.

A. The smokiness of granitic quartz depends mainly upon the radioactivity of granite, and this relation has been easily recognizable to field geologists. The present author collected many samples of granite from various localities. And the relation between smokiness of quartz and rock radioactivity was seen in any granitic mass. In granite samples of fairly high radium content ($2—3\times10^{-12}$ g/g), *i.e.* 10 gram per ton uranium, their quartz are considerably smoky, and on the contrary, quartz included in feeble radioactive granite (under 10^{-12} g/g radium) shows no appreciable smokiness. The same relation is seen also in Ningyotoge and Togo uraniferous arkose sand, Tottori Prefecture. Generally speaking, the order of radioactivity of granitic samples is to be well estimated by the smokiness grade of their quartz.

B. One crystal of the granitic quartz shows homogeneous smokiness by natural or artificial gamma irradiation, and the similar rock facies of the same granitic mass show the same order of smokiness grade and *vice versa.*

The same gamma dosage tends to give very different smokiness grades to granitic samples of different petrographic provinces, for example, quartz contained in stock type granite (Naegi, Tanakamiyama and Kitashirakawa) is much more susceptible to gamma irradiation than that of batholith type granite (Ryoke type granite of Kinki District). Gamma irradiation of 10^7 roentgen makes quartz of Hida granite gneiss only very faintly cloudy. Still less susceptible to it were some samples of Korean gneiss.

In smokiness grade, *i.e.* in susceptibility to gamma irradiation, our samples were found as follows:

stock type granite$>$batholith type granite$>$schistosed granite$>$ gneiss

and in the same granite mass, however,

(a) fresh biotite granite$>$muscovite granite,

(b) biotite granite$>$chlorite granite,

(c) granite consisting the wall rock of fault$>$granitic quartz grains in that fault.

From all this it became evident that granite of high temperature is generally more susceptible to gamma-rays than that of low temperature, and so liparite is the most susceptible.

Wide range reconnaissance investigation was made as regards the smokiness grade on various rock quartz samples. And it is undeniable that volcanic rock quartz usually in β form, despite its feebler radioactivity, is much more smoky than the granitic and the gneissose.

QUARTZ OF EXTRUSIVE ROCK

This paper intends chiefly to find what differences of rock quartz lie between some plutonic rocks and their corresponding extrusives, and to consider what implications these differences have geologically.

The present author has noticed the differences of natural smokiness grade between the quartz of granite and that of quartz porphyry at Kitashirakawa, Kyoto City, both having similar radioactivity. According to Asayama[9], the radium content of quartz porphyry, composing a large dyke in Kitashirakawa granite, is 1.25 and 1.18×10^{-12} g/g, and that of granite itself is 1.22—1.38×10^{-12} g/g. These two rock facies of similar radium content show almost the same chemical composition. In natural smokiness of quartz, volcanic β form quartz of this dyke rock surpasses that of granite. Generally, volcanic porphyritic quartz is much more affected by rock radioactivity than granitic one. Though it is assumed that the above mentioned two rocks are nearly the same in their geologic age, it follows that quartz porphyry has greater susceptibility to natural gamma irradiation than granite.

Now some experimental data by cobalt gamma irradiation will be presented here. Rock quartz (Naegi quartz porphyry, Kumano liparite and dacite tuff of Kasugayama, Nara City) shows far larger smokiness grade than those of granite. And this mineralogical difference between extrusive and granitic rock is clearly indicated by the respective smokiness grades of their quartz. Dacite tuff in Nara seems to have been quenched from high temperature, and its quartz has the largest smokiness grade.

HEATING TREATMENT AND SMOKINESS GRADE

As already stated, the original sample of quartz grains is heated at 600°C for about 5 minutes, and the repetition of the treatment of this order does not change the smokiness grade. But, if heated over 900°C for 30 minutes, the smokiness grade is increased in quartz of any smokiness grade.

For instance, some hydrothermal vein quartz shows only very faint smokiness after 10^7 roentgen irradiation, but becomes much smokier, after the heating treatment of 1000°C for 30 minutes, by the same dosage of gamma irradiation. Similar increase of smokiness was observed in the quartz of crystalline schist of Sanbagawa which remains unaffected by gamma irradiation of 10^7 roentgen.

This heating test was performed in a fused silica glass tube at regulated temperature, and the sample was quenched after heated sufficiently long. In this experiment there is no danger of any minor impurities going into the crystal lattice from outside the quartz grain.

This heat treatment seems to render the quartz crystal structure more imperfect, and this experiment suggests whether the temperature of quartz crystallization was high or low.

The author intends to study also the pressure effect on the smokiness grade of quartz, but this effect does not seem to be so large as that of temperature.

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